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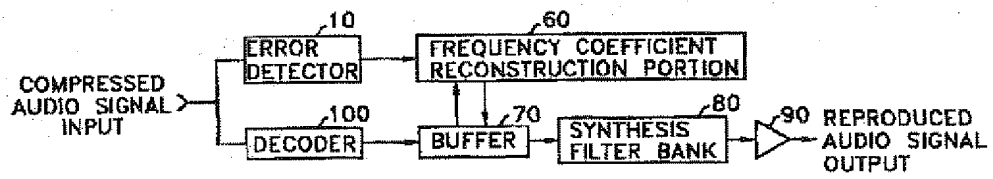
(54) Error concealment method and apparatus of audio signals

(57) An apparatus for concealing a frame or multiple of frames where errors have occurred in a digital audio signal which is subband coded and transform coded in units of an error-correctible frame is described. The error concealment apparatus includes an error detector (10) for receiving frequency coefficients representing the encoded digital audio signal and detecting whether an error has occurred for each frame, a decoder (100) for decoding the frequency coefficients by respective subbands forming a frequency domain of the whole audio signal with respect to the input frequency coefficients, a buffer (70) for storing the frequency coefficients decoded by said decoder (100), a frequency coefficient reconstruction portion (60) for reconstructing the frequency coefficients of a frame or multiple of frames where errors have occurred using predetermined weight values and frequency coefficient(s) of subband adjacent to the error frame(s) among the frequency coefficients belonging to a frame which is stored in the buffer (70) and is adjacent to the error frame(s), and updating the frequency coefficients of the error frame(s), and storing the frequency coefficients in the buffer (70), in response to the error detection result from error detector (10) and a synthesis filter bank (80) for receiving the frequency coefficients stored in the buffer (70) and converting the frequency coefficients into an audio signal of a time domain, in the same sequence as a decoding sequence.

FIG. 5



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Description

The present invention relates to a digital audio receiving apparatus for decoding a compressed audio signal, and more particularly, to an error concealment method and apparatus of an audio signal in which when a particular frame of the compressed audio signal is erroneously lost, the lost frame can be concealed using an adjacent frame or multiple frames of the audio signal.

A subband coding and a transform coding are generally used to compress an audio signal. A conventional digital audio signal encoding/decoding apparatus using a subband coding is schematically shown in figure 1. In figure 1, an analysis filter bank 1A within an encoder 1 divides an input audio signal into K frequency bands. Down-sampling blocks 1B down-sample or decimate each divided frequency band signal into 1/K times a sampling frequency of the input audio signal. Quantization blocks 1C quantize the sampled signal. The quantized signals are transmitted to a receiving end in units of a frame. Then, a decoder 2 of the receiving end reproduces an original audio signal through an inverse signal processing procedure of the encoder 1.

The apparatus of figure 1 processes the audio signal in units of a frame. The frame is the minimum unit which can detect an error generated in the audio signal during the transmission of the compressed audio signal. When the number of the samples in a frame of the audio signal is N, analysis filter bank 1A divides the one frame samples into K subbands. Each down-sampling block 1b down-samples (or decimates) each subband signal into 1/K times a sampling frequency. Accordingly, a total m(=N/K) samples (or frequency coefficients) exist for every frame with respect to one subband. when a set of all frequency coefficients in the same time is a "segment", one frame is composed of m segments S_1-S_m and the number of the frequency coefficients of each segment is K. The segments S_1-S_m with respect to succeeding three frames F_1, F_2, and F_3 are shown in figure 2.

The frequency coefficients of each segment pass through inverse quantization blocks 2A, and over-sampling blocks 2B for over-sampling respective subband signals into K times sampling frequency, consequently to be input to a synthesis filter bank 2C, in decoder 2. Synthesis filter bank 2C inversely transforms the input frequency coefficients into signals in a time domain, and then multiplied by a given windowing function. Therefore, the audio signal in the time domain which is reconstructed at a certain time can be obtained by a total sum of values of the inversely transformed signal from all segments multiplied by the windowing function at a corresponding point of time. Here, the windowing function is used to reduce discontinuities between edges of the succeeding frames. One example of the windowing function is shown in figure 2. Due to the use of such a windowing function, the audio signal of the reconstructed one frame is influenced by the frequency coefficients of each segment of a previous frame and a following frame.

A conventional error concealment apparatus is shown in figure 3, which prevents a signal from being lost when an error occurs in one frame. The figure 3 apparatus performs error concealment with respect to the audio signal compressed by a subband coder or a transform coder. The operation of the figure 3 apparatus will be described below with reference to figures 4A-4C.

A decoder 20 decodes a received compressed audio signal, and an error detector 10 performs error detection in units of a frame. Decoder 20 is composed of an inverse quantizer, an over-sampler and a synthesis filter bank, in the same manner as that of decoder 2 in figure 1. The audio signal output from decoder 20 is applied to a switch 30. The audio signal of the previous frame stored in a frame buffer 40 is also applied to switch 30. Switch 30 selects the signal from decoder 20 or frame buffer 40 according to a control signal output from error detector 10 and supplies the selected signal to frame buffer 40. In case of the frame where an error has not been detected, error detector 10 controls switch 30 so that the signal from decoder 20 is applied to frame buffer 40. Meanwhile, when an error is detected, error detector 10 controls switch 30 so that the signal fedback from frame buffer 40 is supplied to frame buffer 40. For example, when a frame F_2 among three frames F_1, F_2 and F_3 shown in figure 4A can not be reconstructed properly by an error, error detector 10 controls switch 30 so that the signal fedback from frame buffer 40 is again supplied to frame buffer 40. The audio signal output from frame buffer 40 is converted into an analog signal by digital-to-analog converter (DAC) 50.

Concerning the cases where the error occurs and does not occur, the signals which are finally reproduced by the figure 3 error concealment apparatus are shown in figure 4B. Since continuities between the adjacent frames are maintained by using the windowing function shown in figure 4C, the signal represented by a dotted line becomes the finally reproduced signal with respect to frames F_2 and F_3 of figure 4B when frame F_2 is properly reconstructed. On the other hand, when frame F_2 is not properly reconstructed by an error, frame F_2 is replaced by an audio signal of previous frame F_1 shown in figure 4B. The signal which is finally determined with respect to frame F_2 is shown as a solid line in figure 4B. As can be seen from figure 4B, although an error does not occur in frame F_3, the audio signal is influenced by frame F_2 in which an error has occurred. The reason is because decoder 20 uses a windowing function of frame F_2 represented as a dotted line in figure 4C in the audio signal of frame F_2 in which an error has occurred and processes the compressed audio signal of frame F_3 so that continuities between the audio signal of the frame F_2 in this manner and that of the following frame F_3 are maintained. Thus, the reproduced audio signal of frame F_3 becomes a signal represented as a solid line in figure 4B. This signal shows a remarkable difference from a waveform shown as a dotted line, that is, a reproduced signal of frame F_3 when an error does not occur in frame F_2. Therefore, it is not proper that a signal of frame F_2 which is not reconstructed by error occurrence is used by reproducing the previous frame F_1 simply. Moreover, when

the audio signal of frame F_2 varies much differently from frame F_1, signal reproduction of a total frame is not much further proper.

Therefore, with a view to solving or reducing the above problems, it is an aim of preferred embodiments of the present invention to provide an error concealment method of an audio signal which can effectively reconstruct frequency coefficients of a frame where an error has occurred using frequency coefficients of contiguous frame or frames.

Another aim of preferred embodiments of the present invention is to provide an apparatus for embodying the above method.

According to a first aspect of the present invention, there is provided an apparatus for concealing a frame where an error has occurred in a digital audio signal which is subband coded and transform coded in units of an error-correctible frame, the error concealment apparatus comprising:

error detection means for receiving frequency coefficients representing the encoded digital audio signal and detecting whether an error has occurred for each frame;

decoding means for decoding the frequency coefficients by respective subbands forming a frequency domain of the whole audio signal with respect to the input frequency coefficients;

buffer means for storing the frequency coefficients decoded by said decoding means;

frequency coefficient reconstruction means for reconstructing the frequency coefficients of a frame where an error has occurred using predetermined weight values and frequency coefficients for each subband adjacent to the frame where the error has occurred among the frequency coefficients belonging to a frame which is stored in said buffer means and is adjacent to the frame where the error has occurred, and updating the frequency coefficients of the frame where the error has occurred and is stored in said buffer means, in response to the error detection result from error detection means; and

a synthesis filter bank for receiving the frequency coefficients stored in said buffer means and converting the frequency coefficients into an audio signal of a time domain, in the same sequence as a decoding sequence.

Preferably, said frequency coefficient reconstructions means uses frequency coefficients of subbands which exist in the very previous frame of the error-generated frame(s) and is adjacent to the error-generated frame(s), to reconstruct the frequency coefficients of subbands of the error-generated frame(s). Preferably, said frequency coefficients to be used for reconstruction belong to the last segment of the frame which is immediately preceding the error-generated frame(s). Said frequency coefficient reconstruction means preferably calculates frequency coefficients corresponding to subbands of the error-generated frame(s), by multiplying the frequency coefficient adjacent to the error-generated frame(s) which belongs to the very previous frame for each subband, by a predetermined weight value. Preferably, said predetermined weight values are less than or equal to one.

Alternatively, said frequency coefficient reconstruction means may use frequency coefficients which exist in the very previous frame and the very succeeding frame of the error-generated frame(s) and is adjacent to the error-generated frame(s), to reconstruct the frequency coefficients for subband(s) of the error-generated frame(s). Said frequency coefficients to be used for reconstruction may respectively belong to the last segment of the frame which is immediately preceding the error-generated frame(s) and the first segment of the frame immediately succeeding the error-generated frame(s). Said frequency coefficient reconstruction means may calculate frequency coefficients corresponding to subbands of the error-generated frame(s), by multiplying the frequency coefficient adjacent to the error-generated frame(s) which belongs to the very previous frame for each subband, by a first weight value, multiplying the frequency coefficient adjacent to the error-generated frame(s) which belongs to the very succeeding frame for each subband, by a second weight value, and adding the two multiplication results. Said first and second weight values may be less than or equal to one.

According to a second aspect of the invention, there is provided a method for concealing a frame where an error has occurred in a digital audio signal which is subband coded and transform coded in units of an error-correctible frame, the error concealment method comprising the steps of:

(a) receiving frequency coefficients representing the encoded digital audio signal;

(b) detecting whether an error has occurred for each frame with respect to the input frequency coefficients;

(c) decoding the frequency coefficients by respective subbands forming a frequency domain of the whole audio signal with respect to the input frequency coefficients;

(d) storing the frequency coefficients decoded in step (c);

(e) reconstructing the frequency coefficients of a frame or multiple of frames where errors have occurred using predetermined weight values and frequency coefficients of subbands adjacent to the error frame(s) among the frequency coefficients belonging to a frame adjacent to the error frame(s), in response to the error detection result in step (b);

(f) updating the frequency coefficients of the error frame(s) stored in step (d) with the frequency coefficients reconstructed in step (e); and

(g) converting the frequency coefficients resulting from step (f) into an audio signal of a time domain, in the same sequence as that decoding in step (c).

Said step (e) may use frequency coefficients subbands which exist in the very previous frame of the error-generated frame(s) and is adjacent to the error-generated frame(s), to reconstruct the frequency coefficients of subbands of the error-generated frame(s). Said frequency coefficients may belong to the last segment of frame which is immediately preceding the error-generated frame(s). Said step (e) may calculate frequency coefficients corresponding to subbands of the error-generated frame(s), by multiplying the frequency coefficient adjacent to the error-generated frame(s) which belongs to the very previous frame for each subband, by a predetermined weight value. Said predetermined weight values may be less than or equal to one.

Alternatively, said step (e) may use frequency coefficients for subband(s) which exist in the very previous frame and the very succeeding frame of the error-generated frame(s) and is adjacent to the error-generated frame(s), to reconstruct the frequency coefficients for each subband of the error-generated frame(s). Said frequency coefficients may respectively belong to the last segment of the frame which is immediately preceding the error-generated frame(s) and the first segment of the frame succeeding the error-generated frame(s). Said step (e) may calculate frequency coefficients corresponding to subbands of the error-generated frame(s), by multiplying the frequency coefficient adjacent to the error-generated frame(s) which belongs to the very previous frame for each subband, by a first weight value, multiplying the frequency coefficient adjacent to the error-generated frame(s) which belongs to the very succeeding frame for each subband, by a second weight value, and adding the two multiplication results. Said first and second weight values may be less than or equal to one.

Preferably, said step (e) replaces said predetermined weight values for the audio muting by a value of zero, when the number of the succeeding frames where errors have occurred is larger than or equal to a predetermined number.

According to a third aspect of the invention, there is provided a method for concealing a frame where an error has occurred in a digital audio signal which is subband coded and transform coded in units of an error-correctible frame, the error concealment method comprising the steps of:

(a) receiving frequency coefficients representing the encoded digital audio signal;

(b) detecting whether an error has occurred for each frame with respect to the input frequency coefficients;

(c) decoding the frequency coefficients by respective subbands forming a frequency domain of the whole audio signal with respect to the input frequency coefficients;

(d) storing the frequency coefficients decoded in step (c);

(e) reconstructing the frequency coefficients of a frame where errors have occurred using predetermined weight values and frequency coefficients of frame or multiple of frames adjacent to the frame where the error has occurred in response to the error detection result in step (b);

(f) replacing the frequency coefficients of the frame where the error has occurred by the frequency coefficients reconstructed in step (e); and

(g) converting the frequency coefficients resulting from step (f) into an audio signal of a time domain, in the same sequence as that decoding in step (c).

For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example, to the accompanying diagrammatic drawings, in which:

Figure 1 is a schematic block diagram of a conventional digital audio signal encoding/decoding apparatus using a subband coding method;

Figure 2 is a graphical view for explaining a digital audio signal;

Figure 3 is a block diagram showing a conventional error concealment apparatus for a digital audio signal;

Figure 4A-4C are waveform diagrams for explaining error concealment in the figure 3 apparatus;

Figure 5 is a block diagram showing an error concealment apparatus of a digital audio signal according to a preferred embodiment of the present invention;

Figures 6A and 6B are conceptual diagrams for explaining a signal processing of a frequency coefficient reconstruction portion according to the error concealment method provided in embodiments of the present invention;

Figure 7 is a graphical view showing one example of a weight value (α_1) by which a frequency coefficient is multiplied; and

Figures 8A and 8B are conceptual diagrams for explaining a signal processing of a frequency coefficient reconstruction portion according to another error concealment method provided in embodiments of the present invention.

Preferred embodiments of the present invention will be described below in more detail with reference to the accompanying drawings figures 5 through 8B.

The figure 5 apparatus reconstructs an audio signal compressed by the block such as encoder 1 in figure 1 for a digital audio signal. An error detector 10 detects whether an error has occurred for each frame of the input compressed audio signal, and generates an error frame indication signal representing that a frame can not be reconstructed due to an error. A decoder 100 decodes the compressed audio signal in a frequency domain. With respect to the audio signal compressed by encoder 1 of figure 1, the signal input to decoder 100 becomes frequency coefficients of respective subbands. In this case, decoder 100 generates inversely quantized frequency coefficients. The output signal of decoder 100 is supplied to a buffer portion 70. Buffer portion 70 stores the frequency coefficients. A capacity of storing the data in buffer portion 70 is determined by which method of figure 5 apparatus is designed among error concealment methods explained with reference to figures 6A, 6B, 8A and 8B. Frequency coefficient reconstruction portion 60 reads out a signal which is stored in buffer portion 70 according to the error frame indication signal from error detector 10, and reconstructs the frequency coefficients of the frame where an error has occurred, according to a method to be described later. As a result, the frequency coefficients of the error-generated frame are reconstructed by frequency coefficient reconstruction portion 60. The reconstructed frequency coefficients are applied to buffer portion 70. The frequency coefficients of the error-generated frame which is decoded by decoder 100 in buffer portion 70 are replaced by corresponding frequency coefficients reconstructed by frequency coefficient reconstruction portion 60. Buffer portion 70 outputs the stored frequency coefficients in sequence matching a frame sequence to synthesis filter bank 80. Synthesis filter bank 80 multiplies the frequency coefficients of each frame supplied from buffer portion 70 by a windowing function, and transforms the resultant signal into a signal in the time domain. A digital-to-analog converter (DAC) 90 converts the signal applied from synthesis filter bank 80 into an analog signal. Therefore, the output signal from DAC 90 becomes a reproduced audio signal in which the generated error is concealed.

An operation of frequency coefficient reconstruction portion according to the exemplary methods proposed will be described below with reference to figures 6A and 6B. The error concealment method shown in figures 6A and 6B reconstructs the frequency coefficients of each segment in a frame where an error has occurred, using a frequency coefficient of the last segment of a previous frame. With respect to the subband coded audio signal, frequency coefficient reconstruction portion 60 reconstructs the frequency coefficients of the error-generated frame by the respective subbands. Figure 6A shows a case where one frame F_2 is not decoded due to an error. In this case, a value of the frequency coefficient of a first segment S_1 in frame F_2 becomes a value obtained by multiplying the frequency coefficient of the M-th segment S_m being the last segment in frame F_1 by weight value α_1. A coefficient of second segment S_2 is obtained by multiplying a coefficient of first segment S_1 by weight value α_2. The following segments S_3-S_m are processed in the same manner as the above. Thus, the frequency coefficients of the whole segments S_1-S_m belonging to frame F_2 where an error has occurred are reconstructed. Here, weight values ($\alpha_1, \alpha_2, \ldots, \alpha_m$) are positive integers which are generally less than or equal to one and can be determined by a user. For example, if $\alpha_1=\alpha_2,\ldots,\alpha_m=\alpha<1.0$, the frequency coefficients of respective segments S_1-S_m within frame F_2 are obtained by the following expressions.

$$\text{Coefficient}\,(S_1, F_2) \leftarrow \alpha x(S_m, F_1)$$

$$\text{Coefficient}\,(S_2, F_2) \leftarrow \alpha^2 x(S_m, F_1)$$

$$\text{Coefficient}\,(S_m, F_2) \leftarrow \alpha^m x(S_m, F_1)$$

Here, coefficient (S_j, F_i) represents a frequency coefficient belonging to the j-th segment of the i-th frame. At this time, since weight value α is smaller than one, the later the segment is located in one frame, the more sharply the frequency coefficient value is lowered. Such an example is shown in figure 7.

As shown in figure 6B, when succeeding errors occur in several contiguous frames EF_1, EF_2,...,EF_n, the frequency coefficient of the last segment in frame F_1 where an error does not occur, is used to reconstruct the frequency coefficients

of all frames EF_1, EF_2,...,EF_n which are located succeedingly. To reconstruct the frequency coefficients of frames EF_1, EF_2,...,EF_n, a method similar to that explained with reference to figure 6A is applied. As a result, the frequency coefficient value of the m-th segment S_m in the last frame EF_n becomes a value obtained by multiplying the previous weight values in all the error-generated frames. It is preferable in this case that the different weight values can be used in the respective error-generated frames EF_1, EF_2,...EF_n. For example, the following expressions can be given.

$$EF_1 \leftarrow \alpha_1=0.9,\ \alpha_2=....\alpha_m=1$$

$$EF_2 \leftarrow \alpha_1=0.8,\ \alpha_2=....\alpha_m=1$$

$$EF_3 \leftarrow \alpha_1=0.6,\ \alpha_2=....\alpha_m=1$$

$$EF_{(n-1)} \leftarrow \alpha_1=0.1,\ \alpha_2=....\alpha_m=1$$

$$EF_n \leftarrow \alpha_1=\alpha_2=....\alpha_m=0$$

When the weight values are assigned in this way, the frequency coefficient of first segment S_1 in first error-generated frame EF_1 shown in figure 6B is obtained by multiplying the coefficient value of m-th segment S_m in previous frame F_1 by weight value α_1(=0.9). Likewise, the frequency coefficient values of second segment S_2 in first error-generated frame EF_1 is obtained by multiplying the first coefficient values by weight value α_2. Thus, up to the (n-1)-th error-generated frame EF_1-$EF_{(n-1)}$, a reproduced signal is made using a reconstructed frequency coefficient of the previous frame. However, since the weight values of the n-th error-generated frame are all zeros, this interval becomes an audio erasure state. That is, if the weight value is properly adjusted in this manner, an audio muting operation can be performed from any frame.

The above-described method reconstructs the error using the last segment in the previous frame prior to error occurrence, for more convenient explanation. It is however possible to use a coefficient of a different segment which is located near the last segment of the previous frame or future frame.

Figures 8A and 8B are views for explaining a further error concealment method modifying the error concealment method explained with reference to figures 6A and 6B. The error concealment method proposed in connection with Figures 8A and 8B calculates the frequency coefficients of the frame where the error has occurred, through an interpolation operation using a frequency coefficient of the previous frame with respect to the error-generated frame and the frequency coefficient of the following frame with respect to the error-generated frame. The method for calculating the frequency coefficient values of error-generated frame F_2 will be described below. In case of figure 8A, the frequency of the first segment S_1 in frame F_2 is obtained by adding a value of a coefficient value of m-th segment S_m in first frame F_1 multiplied by weight value β_1 to a value of a coefficient value of first segment S_1 in third frame F_3 multiplied by weight value $(1-\beta_1)$. This can be represented as follows, in the general form with respect to all segments belonging to frame F_3.

$$\text{Coefficient}(S_1, F_2) \leftarrow \beta_1 \times \text{Coefficient}(S_m, F_1) + (1-\beta_1) \times \text{Coefficient}(S_1, F_3)$$

Figure 8B shows an example where the figure 8A method is adapted in the case where the errors have occurred in the several contiguous frames. Since implementation of the figure 8B method will be apparent to those having skill in the art having read the foregoing description and studied figure 8B, the detailed description will be omitted. The weight values α_1 and β_1 referred to in connection with figures 6A, 6B, 8A and 8B can be obtained by a calculation method and can be used in the form of a look-up table.

As described above, the error concealment method and apparatus according to embodiments of the present invention reconstructs the frequency coefficients of the error-generated frame using the frequency coefficient of the contiguous frame, thereby minimizing an influence on the succeeding frames due to the error-generated frame.

While only certain embodiments of the invention have been specifically described herein, it will be apparent that numerous modifications may be made thereto without departing from the scope of the invention.

The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

Claims

1. An apparatus for concealing a frame or multiple of frames where errors have occurred in a digital audio signal which are subband coded and transform coded in units of an error-correctible frame, said error concealment apparatus comprising:

   error detection means (10) for receiving frequency coefficients representing the encoded digital audio signal and detecting whether an error has occurred for each frame;

   decoding means (100) for decoding the frequency coefficients by respective subbands forming a frequency domain of the whole audio signal with respect to the input frequency coefficients;

   buffer means (70) for storing the frequency coefficients decoded by said decoding means (100);

   frequency coefficient reconstruction means (60) for reconstructing the frequency coefficients of a frame or multiple of frames where errors have occurred using predetermined weight values and frequency coefficients of subband(s) adjacent to the error frame(s) among the frequency coefficients belonging to a frame which is stored in said buffer means and is adjacent to the error frame(s), updating the frequency coefficients of the error frame(s) and storing the frequency coefficients in said buffer means (70), in response to the error detection result from error detection means (10); and

   a synthesis filter bank (80) for receiving the frequency coefficients stored in said buffer means (70) and converting the frequency coefficients into an audio signal of a time domain, in the same sequence as a decoding sequence.

2. An apparatus according to claim 1, wherein said frequency coefficient reconstructions means (60) uses frequency coefficients of subbands which exist in the very previous frame of the error-generated frame(s) and is adjacent to the error-generated frame(s), to reconstruct the frequency coefficients of subbands of the error-generated frame(s).

3. An apparatus according to claim 2, wherein said frequency coefficients to be used for reconstruction belong to the last segment of the frame which is immediately preceding the error-generated frame(s).

4. An apparatus according to claim 2 or 3, wherein said frequency coefficient reconstruction means (60) calculates frequency coefficients corresponding to subbands of the error-generated frame(s), by multiplying the frequency coefficient adjacent to the error-generated frame(s) which belongs to the very previous frame for each subband, by a predetermined weight value.

5. An apparatus according to claim 4, wherein said predetermined weight values are less than or equal to one.

6. An apparatus according to claim 1, wherein said frequency coefficient reconstruction means uses frequency coefficients which exist in the very previous frame and the very succeeding frame of the error-generated frame(s) and is adjacent to the error-generated frame(s), to reconstruct the frequency coefficients for subband(s) of the error-generated frame(s).

7. An apparatus according to claim 6, wherein said frequency coefficients to be used for reconstruction respectively belong to the last segment of the frame which is immediately preceding the error-generated frame(s) and the first segment of the frame immediately succeeding the error-generated frame(s).

8. An apparatus according to claim 6 or 7, wherein said frequency coefficient reconstruction means (60) calculates frequency coefficients corresponding to subbands of the error-generated frame(s), by multiplying the frequency coefficient adjacent to the error-generated frame(s) which belongs to the very previous frame for each subband, by a first weight value, multiplying the frequency coefficient adjacent to the error-generated frame(s) which belongs to the very succeeding frame for each subband, by a second weight value, and adding the two multiplication results.

9. An apparatus according to claim 8, wherein said first and second weight values are less than or equal to one.

10. A method for concealing a frame or multiple of frames where errors have occurred in a digital audio signal which is subband coded and transform coded in units of an error-correctible frame, said error concealment method comprising the steps of:

(a) receiving frequency coefficients representing the encoded digital audio signal;

(b) detecting whether an error has occurred for each frame with respect to the input frequency coefficients;

(c) decoding the frequency coefficients by respective subbands forming a frequency domain of the whole audio signal with respect to the input frequency coefficients;

(d) storing the frequency coefficients decoded in step (c);

(e) reconstructing the frequency coefficients of a frame or multiple of frames where errors have occurred using predetermined weight values and frequency coefficients of subbands adjacent to the error frame(s) among the frequency coefficients belonging to a frame adjacent to the error frame(s), in response to the error detection result in step (b);

(f) updating the frequency coefficients of the error frame(s) stored in the step (d) with the frequency coefficients reconstructed in step (e); and

(g) converting the frequency coefficients resulting from step (f) into an audio signal of a time domain, in the same sequence as that decoding in step (c).

11. A method according to claim 10, wherein said step (e) uses frequency coefficients subbands which exist in the very previous frame of the error-generated frame(s) and is adjacent to the error-generated frame(s), to reconstruct the frequency coefficients of subbands of the error-generated frame(s).

12. A method according to claim 11, wherein said frequency coefficients belong to the last segment of frame which is immediately preceding the error-generated frame(s).

13. A method according to claim 11 or 12, wherein said step (e) calculates frequency coefficients corresponding to subbands of the error-generated frame(s), by multiplying the frequency coefficient adjacent to the error-generated frame(s) which belongs to the very previous frame for each subband, by a predetermined weight value.

14. A method according to claim 13, wherein said predetermined weight values are less than or equal to one.

15. A method according to claim 10, wherein said step (e) uses frequency coefficients for subband(s) which exist in the very previous frame and the very succeeding frame of the error-generated frame(s) and is adjacent to the error-generated frame(s), to reconstruct the frequency coefficients for each subband of the error-generated frame(s).

16. A method according to claim 15, wherein said frequency coefficients respectively belong to the last segment of the frame which is immediately preceding the error-generated frame(s) and the first segment of the frame succeeding the error-generated frame(s).

17. A method according to claim 15, wherein said step (e) calculates frequency coefficients corresponding to subbands of the error-generated frame(s), by multiplying the frequency coefficient adjacent to the error-generated frame(s) which belongs to the very previous frame for each subband, by a first weight value, multiplying the frequency coefficient adjacent to the error-generated frame(s) which belongs to the very succeeding frame for each subband, by a second weight value, and adding the two multiplication results.

18. A method according to claim 17, wherein said first and second weight values are less than or equal to one.

19. A method according to claim 10, wherein said step (e) replaces said predetermined weight values for the audio muting by a value of zero, when the number of the succeeding frames where errors have occurred is larger than or equal to a predetermined number.

FIG. 1 (PRIOR ART)

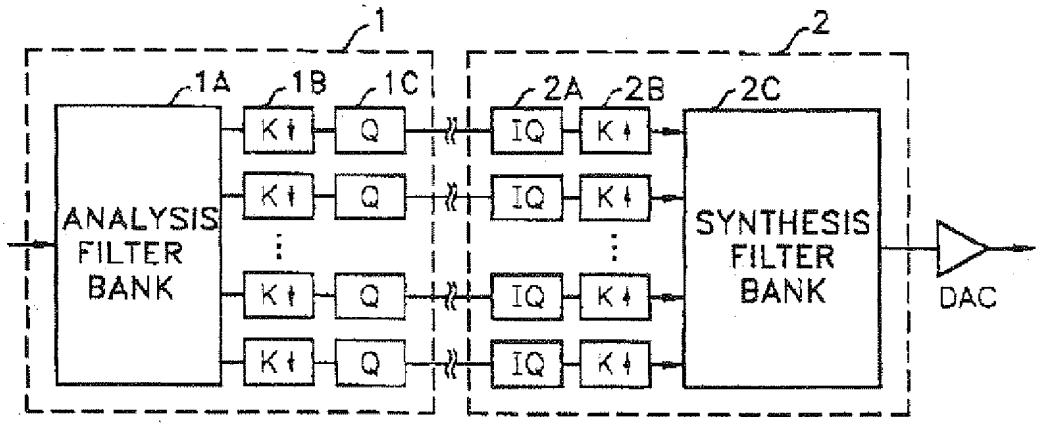


FIG. 2 (PRIOR ART)

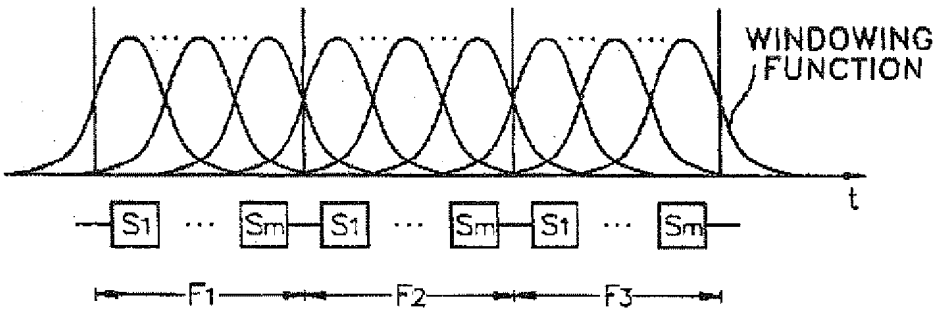


FIG. 3 (PRIOR ART)

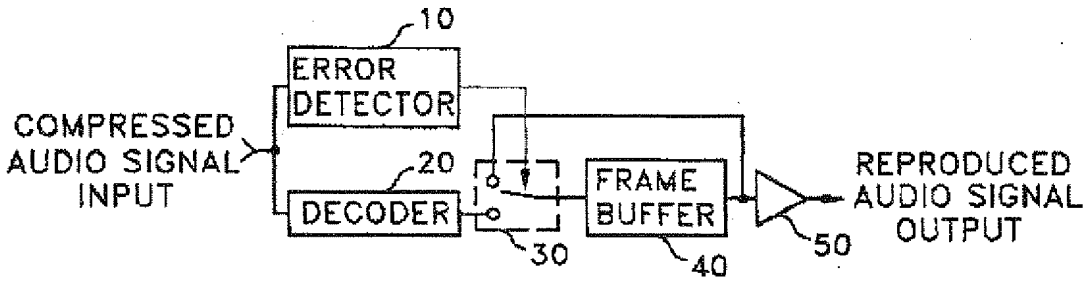


FIG. 4 A (PRIOR ART)

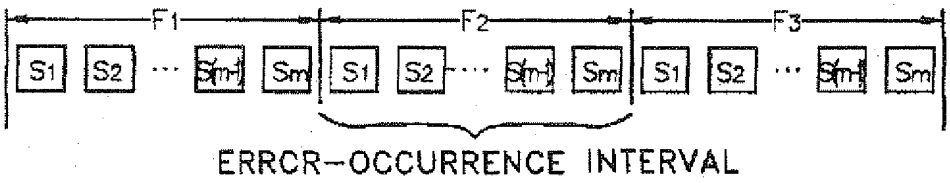


FIG. 4 B (PRIOR ART)

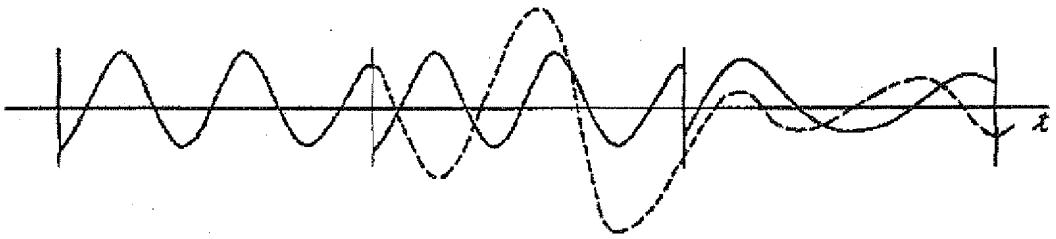


FIG. 4 C (PRIOR ART)

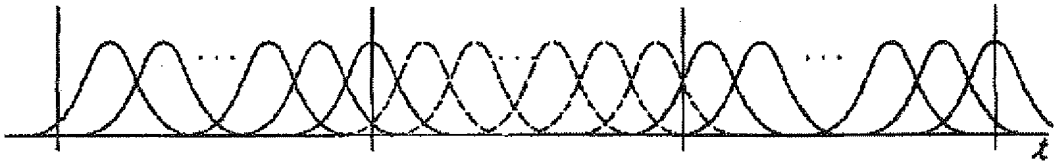


FIG. 5

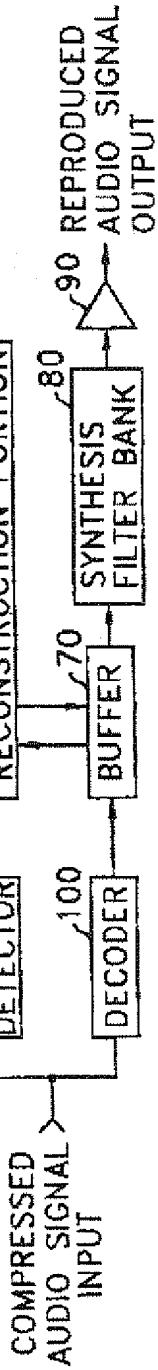

COMPRESSED AUDIO SIGNAL INPUT
10
ERROR DETECTOR
100
DECODER
60
FREQUENCY COEFFICIENT RECONSTRUCTION PORTION
70
BUFFER
80
SYNTHESIS FILTER BANK
90
REPRODUCED AUDIO SIGNAL OUTPUT

FIG. 6A

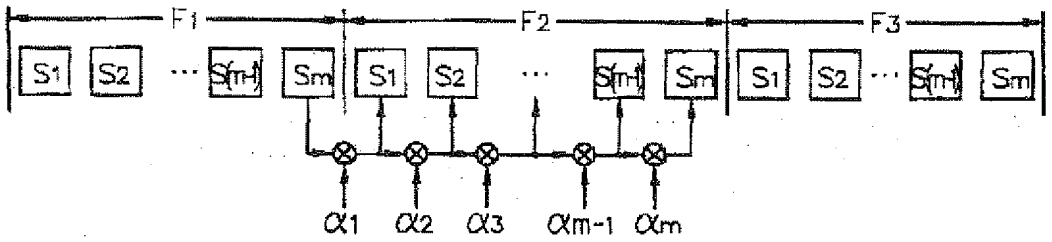


FIG. 6B

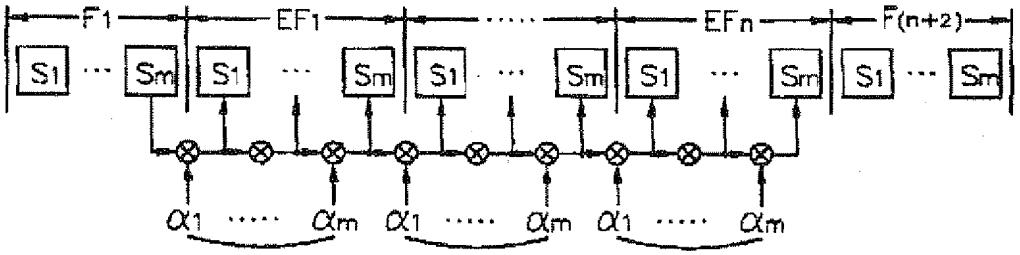


FIG. 7

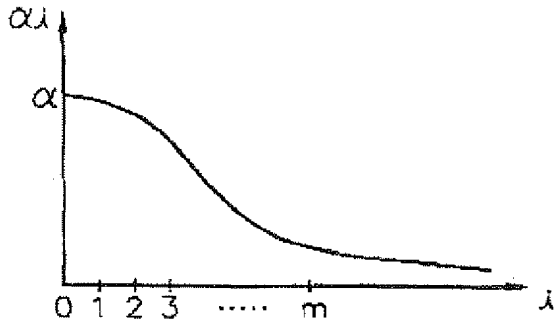


FIG.8A

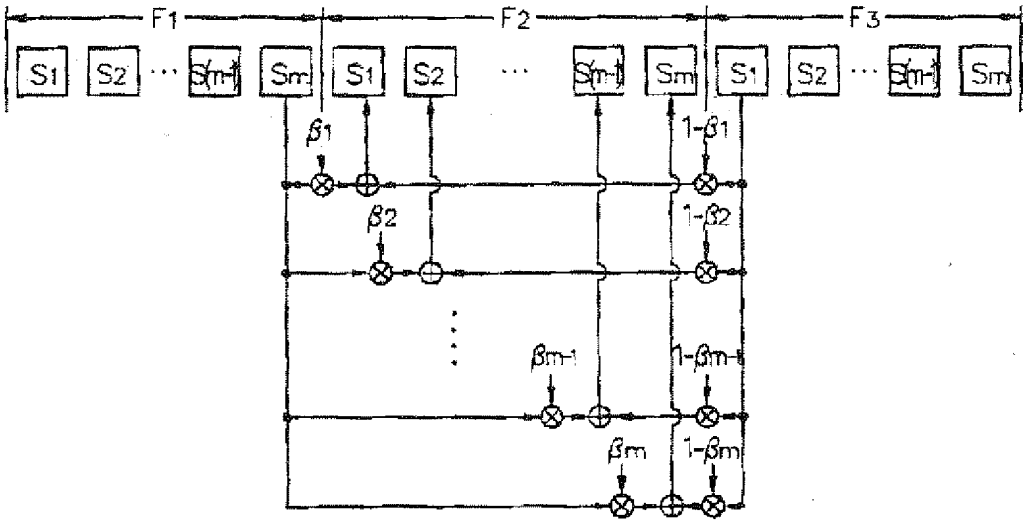
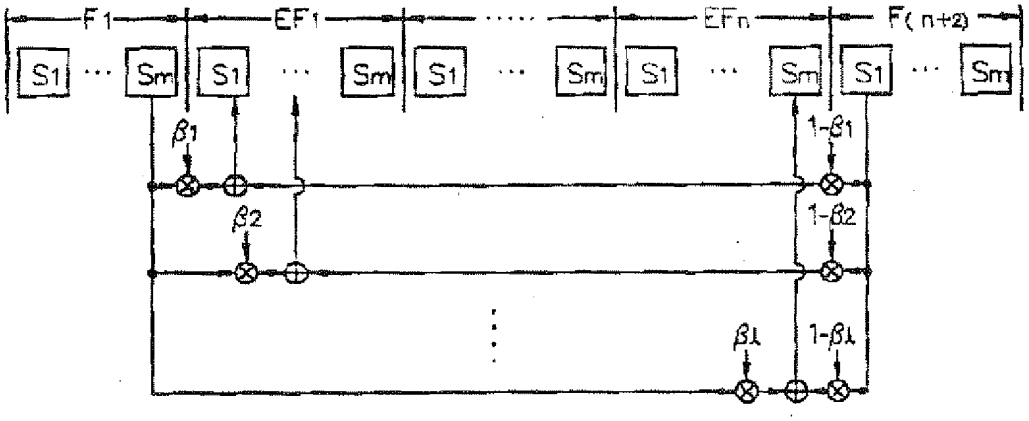

F1
F2
F3
S1
S2
Sm-1
Sm
β1
β2
βm-1
βm
1-β1
1-β2
1-βm-1
1-βm

FIG.8B


F1
EF1
EFn
F(n+2)
S1
Sm
β1
β2
βL
1-β1
1-β2
1-βL